

A Novel Approach for Robust Power Quality Correction and Enhancement in OG-HPS using IMDGU and ZRU

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ABSTRACT: Generally the micro grid system is a large scale power distribution network of very complex architecture, satisfying the needs of common electrical loads. This giant class power system lacks in ability to serve the hilly, remote and terrain regions by its power due to their hard striking non-homogeneous geographical conditions, under which renewable energy based Off-Grid Hybrid Power System (OG-HPS)s, were emerged as the reliable alternative. But very often due to the time based fluctuations of the renewable power levels and frequent line faults, the power quality of OG-HPS may be degraded. As an eternal solution to this ever teasing problem, in this paper we proposed a robust IMDGU and ZRU based approach for power quality enhancement and regulation in OG-HPS. The proposed approach was realized with an Intelligent Module Distribution Generation Unit(IMDGU) as a core processing unit, internally which comprises a Phasor Measurement Unit(PMU) intended for an instantaneous detection and isolation of the network line faults, a Power Quality Regulation Unit(PQRU) meant for power quality restoration and a Zener Regulation Unit(ZRU) for power quality regulation as sub-core processing units. As a prime commanding module, the IMDGU will provide an adaptive fault security, real-time correction and regulation of the distributed power quality by properly steering the operational control of all sub-core processing units. The proposed approach is coded, simulated and tested in the Mat lab Environment. Simulation results adjudged that the proposed approach is the best in all aspects and outperforms all the existing techniques.

KEYWORDS: HPS, OG-HPS, IMDGU, Fault Isolation, ZRU.

I.INTRODUCTION

The electrical energy is the most prominent form of energy on which modern society is heavily dependent, in the absence of which the human life is very hard to imagine. The Majority of world population lives in remote villages to where the conventional grid systems were failed to spread their roots due to very complex geographical conditions and expensive network structure. Not only were the remote villages, but also in the case of remote areas, hilly and terrain regions, and geographically uneven dense forest areas the conventional grid systems failed in electrifying them. Under these conditions the Off-Grid Power System (OGPS) s realized with a hybrid combination of different renewable power generation units were found to be the best alternative for the electrification of these areas. In India, the Ministry of New and Renewable Energy (MNRE) has setup a Village Energy Security Programme (VESP) under which plenty of off-grid biomass power plants were setup. The power quality may be affected due to undesirable oscillations in voltage and frequency of power being supplied, harmonics, transients, sudden switching operations, voltage fluctuations etc., which are collectively responsible for the utility performance and life time deterioration. A switchgear real time system capable enough to clear the faults at rapid rate must be designed to operate with power distribution system[6] to maintain the continuity of power supply.

Distributed Generation[7] (DG) unit being an electrical power generation unit connected directly to a distribution network [8] adopts the technologies which will vary in methods of generation including small-scaled gas turbines,

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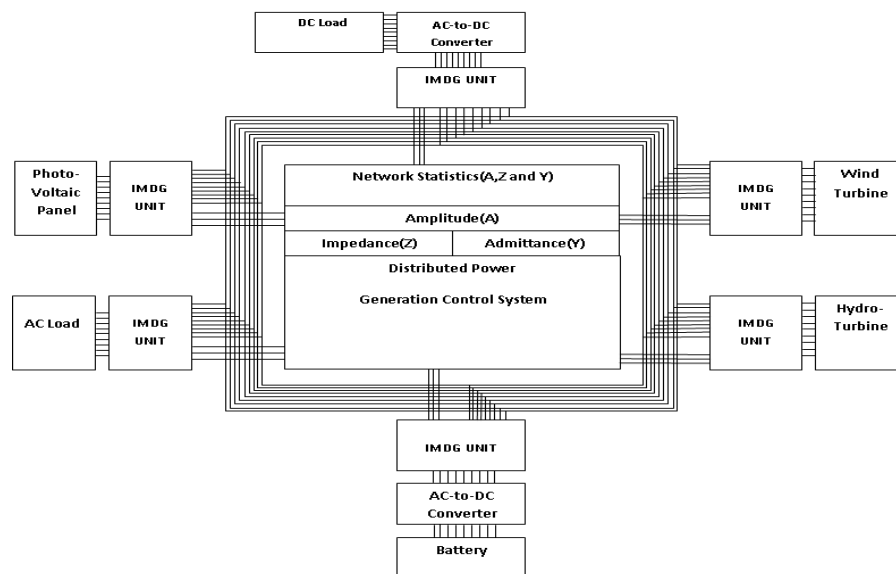
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wind-farms, fuel cells, solar energy and hydro power plants, etc [1]. The DPS consisting of a number of radial feeders are normally subjected to various types of faults caused by storm, lightning, snow, freezing, rain, insulation breakdown, and short circuit faults caused by birds and other exterior objects, due to which the desired reliability cannot be achieved easily. To ensure the reliability of DPS, utility should be able to detect and recognize the fault spot[2] and type immediately after the fault was occurred. The faster the fault location [4][5] is identified or at least estimated with reasonable accuracy, the more accelerated the maintenance time to restore normal power supply.

Though the DG unit may offer solutions to majority of power systems crave. However, their installation at non-optimal place may the cost due to increase in system losses. As the Off-Grid -Hybrid Power Systems (OG-HPS) were considered as a reliable option for the electrification of remote rural villages which are beyond the reach of micro-grid electricity, the control of power among different renewable generation units while maintaining the power quality of supply is important for the reliable and sustainable operation of these OG-HPS. For this purpose many algorithms are proposed in the literature but their performance was not up to the satisfactory level, that is demanded by the real time applications. Hence as an attempt to provide an eternal solution to these ever teasing limitations of OG-HPS we developed this project to enable the robust fault free, power quality enhanced and regulated operation of the OG-HPS using IMDGU and ZRU.

II. PROPOSED WORK

In this project we proposed a novel approach for an efficient power quality improvement and regulation using the robust IMDGU and ZRU as core processing blocks. The IMDGU with a novel design procedure inherently uses the PMUs for efficient fault protection[3] and the PQRU for power quality improvement and regulation of OG-HPS to ensure the fault protected and power quality enhanced operation of OG-HPS. The constructed IMDG unit will act as DG unit to improve the voltage profile and to reduce the losses. The schematic block diagram of the proposed OG-HPS system is shown in figure (1).



Fig(1): Schematic block diagram of the proposed DG-HPS System.

The proposed OG-HPS implements a ring bus architecture which enables it to serve the regions surrounding it with its power. An identical bus branch is drawn to each and every region or zone. Each power distribution bus branch is operationally steered by a dedicated IMDGU as shown in figure(1), which will control and monitors it for faults and acts accordingly to detect and isolate them without showing any impact on the power quality and operational

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effectiveness of the OG-HPS. With the database of rated line parameter values the OG-HPS directs the crew IMDGUs for an efficient fault isolation and consequent power quality regulation of its power generation and distribution bus lines with an aid of the Distributed Power Generation Control System (DPGCS), which acts as a prime defense control system for OG-HPS. After the power quality restoration by the PQRU of the IMDGU, the rest of restoration, adequate smoothening and regulation will be carried out by a regulation unit called the Zener Regulation Unit (ZRU). The ZRU implements a high-class power regulation circuitry using the Zener diode based power regulation units. ZRU inherently implements a separated Regulation Unit (RU) for each individual bus lines. ZRU is intended to provide an adequate perfect power regulation in OG-HPS. The operation of all individual IMDGU and ZRU is conditionally steered by the DPGCS unit using three associated control lines such as IMDGCN to control the enable/disable status of the IMDGU, IMDGS to check the operational activeness of the discrete IMDGU components and IMDGES to check the IMDGU malfunction status. The core internal circuit of the IMDGU is shown in figure (2). The IMDGU based DG unit will consist of an IMDGU and its associated breakers. Being the core functional blocks of the IMDGU, the PMU performs adaptive fault protection [3] of OG-HPS with an intelligent real time detection and isolation of frequent line faults, whereas the PQRU regulates the deviated power quality due to power fluctuations caused by several natural and atmospheric conditions which are detected perfectly in quantity and supplied as feedback input to the PQRU block by the PMU block. The inside view of the PMU block consists of a ROM unit, a RAM unit, a mini processor (Line Parameter Calculation Circuits (LPCC)), and a Time Switched Comparator and Decision Making Device (TSC-DMD) units as shown in figure(2).

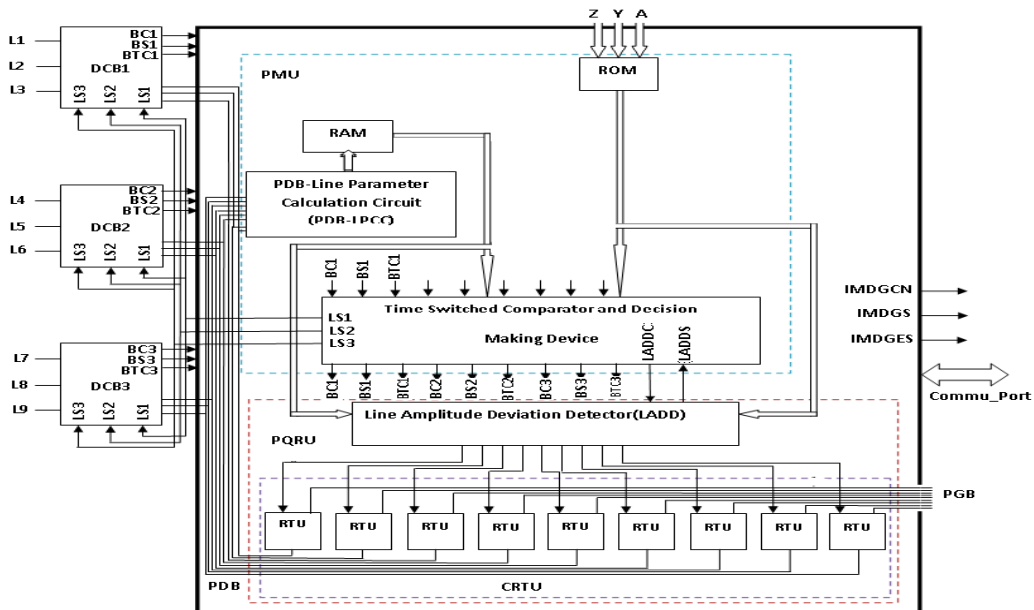


Fig (2): Schematic block diagram of the proposed DG unit.

A dedicated LPCC calculates the instantaneous line parameter values of power generation and distribution bus lines and stores them in their associated RAM units. The ROM unit keeps a copy of the rated parameter values from the data base unit of the OG-HPS. The TSC-DMD unit accepts the instantaneous and rated line parameter values along with the control, status and trip signals of the individual breakers as input and processes them accordingly to issue the necessary control signals to all breakers on power generation and distribution sides to ensure the fault free and power quality regulated operation of the proposed OG-HPS. The Control signal logical definitions are given as

IMDGCN → IMDGU control signal; If IMDGCN=1; IMDGU is enabled, otherwise disabled.

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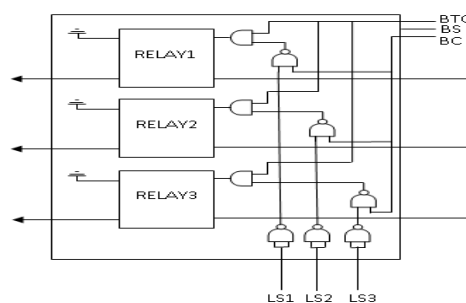
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IMDGS→ IMDGU Operational Status. If IMDGS=1; all the discrete components of the IMDGU are working perfectly and the IMDGU is active at this instance of operation, otherwise inactive.

IMDGES→IMDGU Error Status. If IMDGES=1; there is a line fault in the bus branch being monitored by this IMDGU. Otherwise no fault.

The DPGCS unit receives the instantaneous operational status of all IMDGUs in the form of a detailed text message format to examine their operational condition and to act accordingly. If a message stating an error in the operational condition of a particular IMDGU was received by the DPGCS, the DPGCS unit passes the messages received from the corresponding IMDGU which is monitoring the faulted bus branch for faults to the technical department. Since this message from the IMDGU consists of a detailed information about the operational conditions of the region to which it is assigned as an independent region monitoring device, if any line fault is occurred in a region, then that fault condition is precisely identified by its type, location and number of the line suffering from the fault and the same information is informed to the technical department so as enable faster recovery of faults with negligible amount of delay and man power. The PMU module will sense the line faults and isolates them immediately and calculates the power quality differences between the instantaneous and rated power levels and informs the same to the PQRU for instantaneous power quality correction. The PQRU which is shown in fig(2),internally consists of a Line Amplitude Deviation Detector(LADD),which will detects and calculates the power quality fluctuations in quantitative terms and a Cascaded Reconfigurable Transformer Unit(CRTU)s,which is meant to restore the fluctuated power levels on the bus lines with a suitable step up/step down action of the transformer units. The CRTU unit consists of a cascade connected Reconfigurable Transformer Unit (RTU) s, one for each bus line. The computed power quality deviations of each bus line by the LADD unit are supplied as the feedback input to the corresponding RTU in the CRTU,so as to regulate the power quality deviations and to ensure the power quality enhanced operation of the OG-HPS .If there is no deviation in the power quality of a particular bus line, no step up /step down process is carried by an associated RTU of the line, but it will just acts as an auto transformer without any step up/step down process, there by maintaining the same power quality on the line without any change. The PQRU block is internally put under the control of the PMU block with an aid of two control signals such as LADDC and LADDS.LADDC stands for Line Amplitude Deviation Detector Control(LADDC),where as LADDS stands for Line Amplitude Deviation Detector Status(LADDS).An active high status of LADDC enables LADD, otherwise disabled. Similarly active high status of LADDS indicates the active status of internal discrete components of LADD, otherwise inactive. The internal architecture of the breaker circuit is shown in below figure (3), which employ three relay circuits to control three lines one for each line and the associated control circuitry. Each relay will look over the close or open status of one bus line. Each breaker has three control pins such as BC, BS and BTC with access of which the associated IMDGU controls its operation. Thus the PQRU will acts as the Power Fluctuation Regulator (PRF).If a fault is occurred in a particular breaker lines, then it will get tripped by making its BTC=1 and based on the logic levels on Line Status (LS)pins such as LS1,LS2 and LS3,the relay of the particular faulted line will be discharged. When LS1=0; then the first line of the breaker will be faulty and hence isolated from the network. Similarly, if LS2=0, second line of the breaker will be isolated and if LS3=0 then the third line of the breaker will be isolated.



Fig(3):Internal architecture of the breaker circuit.

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III.RESULTS AND DISCUSSION

The algorithm is designed, programmed with six operational zones for simplicity, which can be extended further to any number of regions or zones with relatively less operational overhead costs and simulated using Matlab to test its operational effectiveness. First and Foremost the OG-HPS initializes all its IMDGUs with the rated parameter values of line voltage, line currents and associated phase deviations as given in table (1), table (2) and table (3).

IntializingThe Network Rated Line Voltages.....			IntializingThe Network Rated Line Currents.....			IntializingThe Network Rated PHASE Voltages.....		
SNO	BUS LINE	RATED VOLTAGE LEVELS(in V)	SNO	BUS LINE	RATED CURRENT LEVELS(in A)	SNO	BUS LINE	RATED PHASE VOLTAGE LEVELS(in V)
1	LINE1	400	1	LINE1	50	1	LINE1	230
2	LINE2	400	2	LINE2	50	2	LINE2	230
3	LINE3	400	3	LINE3	50	3	LINE3	230
4	LINE4	400	4	LINE4	50	4	LINE4	230
5	LINE5	400	5	LINE5	50	5	LINE5	230
6	LINE6	400	6	LINE6	50	6	LINE6	230
7	LINE7	400	7	LINE7	50	7	LINE7	230
8	LINE8	400	8	LINE8	50	8	LINE8	230
9	LINE9	400	9	LINE9	50	9	LINE9	230

Table (1): Network Rated Line Voltages.

Table (2): Network Rated Line Currents.

Table (3): Network Rated Phase Voltages.

IntializingThe Network Rated PHASE Voltages.....		
SNO	BUS LINE	RATED PHASE VOLTAGE LEVELS(in V)
1	LINE1	230
2	LINE2	230
3	LINE3	230
4	LINE4	230
5	LINE5	230
6	LINE6	230
7	LINE7	230
8	LINE8	230
9	LINE9	230

Table (3): Network Rated Phase Voltages.

The control signal definitions of the IMDGU for its fault free and faulty operational conditions are given in table (4) and table (5) respectively.

IntializingThe Network IMDG Units.....					
SNO	IMDG Unit	IMDG CONTROL	IMDG STATUS	IMDG ERROR STATUS	OPERATIONAL STATUS
1	IMDGU1	Enabled	Active	No Error	Fault Free
2	IMDGU2	Enabled	Active	No Error	Fault Free
3	IMDGU3	Enabled	Active	No Error	Fault Free
4	IMDGU4	Enabled	Active	No Error	Fault Free
5	IMDGU5	Enabled	Active	No Error	Fault Free
6	IMDGU6	Enabled	Active	No Error	Fault Free

Table (4): Command signal definitions of the IMDGU for fault free operational conditions.

IntializingThe Network IMDG Units.....					
SNO	IMDG Unit	IMDG CONTROL	IMDG STATUS	IMDG ERROR STATUS	OPERATIONAL STATUS
1	IMDGU1	Disabled	Inactive	Error	Faulty
2	IMDGU2	Disabled	Inactive	Error	Faulty
3	IMDGU3	Disabled	Inactive	Error	Faulty
4	IMDGU4	Disabled	Inactive	Error	Faulty
5	IMDGU5	Disabled	Inactive	Error	Faulty
6	IMDGU6	Disabled	Inactive	Error	Faulty

Table (5): Command signal definitions of the IMDGU for faulty operational conditions.

The simulation results of the proposed OG-HPS for fault free operation are given primarily as follows. Under fault free operation the performance summary of the proposed IMDGU are given in table (6) and table (7) respectively. These definitions are common for all IMDGUs.

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IMDG OPERATIONAL SUMMARY		
SNO	Control Variable	Operational Status
1	IMDG Control	Enabled
2	IMDG Status	Active
3	IMDG Error Status	No Error
4	BR1 Control	Enabled
5	BR2 Control	Enabled
6	BR3 Control	Enabled
7	BR1 Status	Active
8	BR2 Status	Active
9	BR3 Status	Active
10	BTC4 Status	Untrip
11	BTC4 Status	Untrip
12	BTC4 Status	Untrip

Table (6): The operational summary of the IMDGU for fault free operation.

IMDG PERFORMANCE SUMMARY					
SNO	IMDG_BUS_LINE	LINE_STATUS	AMPLITUDE	IMPEDANCE	ADMITTANCE
1	LINE1	Closed	Rated	Rated	Rated
2	LINE2	Closed	Rated	Rated	Rated
3	LINE3	Closed	Rated	Rated	Rated
4	LINE4	Closed	Rated	Rated	Rated
5	LINE5	Closed	Rated	Rated	Rated
6	LINE6	Closed	Rated	Rated	Rated
7	LINE7	Closed	Rated	Rated	Rated
8	LINE8	Closed	Rated	Rated	Rated
9	LINE9	Closed	Rated	Rated	Rated

Table (7): The performance summary of the IMDGU for fault free operation.

The graphical variation of breaker currents of the IMDGU breakers with respect to the operational conditions are illustrated in fig (4)

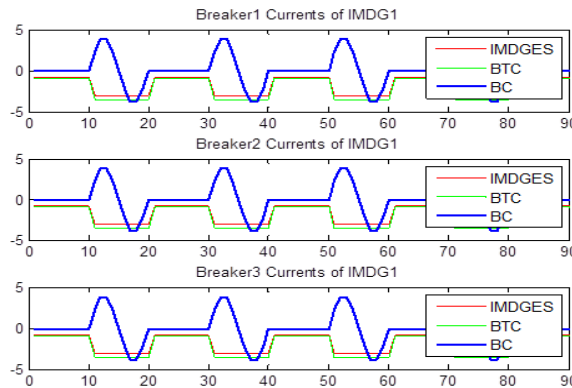


Fig (4): Breaker current waveforms of the IMDGU breakers under fault free condition.

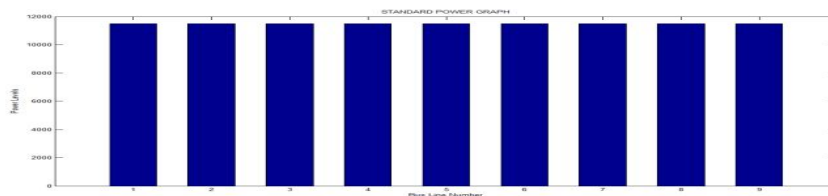


Fig (5): The Standard Power levels of the OG-HPS under fault free operation.

The operational results of the proposed algorithm under faulty conditions of the OG-HPS are presented primarily as follows. Under faulty conditions the operational and performance summary of the proposed IMDGU are given in table (8) and table (9) respectively.

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IMDG1 OPERATIONAL SUMMARY

SNO	Control Variable	Operational Status
1	IMDG Control	Enabled
2	IMDG Status	Active
3	IMDG Error Status	No Error
4	BR1 Control	Enabled
5	BR2 Control	Enabled
6	BR3 Control	Enabled
7	BR1 Status	Active
8	BR2 Status	Active
9	BR3 Status	Active
10	BTC1 Status	Trip
11	BTC2 Status	Untrip
12	BTC3 Status	Untrip

Table (8): The operational summary of the IMDG unit for faulty operation.

IMDG1 PERFORMANCE SUMMARY

SNO	IMDG_BUS_LINE	LINE_STATUS	AMPLITUDE	IMPEDANCE	ADMITTANCE
1	LINE1	Closed	Rated	Rated	Rated
2	LINE2	Opened	Change	Change	Change
3	LINE3	Opened	Change	Change	Change
4	LINE4	Closed	Rated	Rated	Rated
5	LINE5	Closed	Rated	Rated	Rated
6	LINE6	Closed	Rated	Rated	Rated
7	LINE7	Closed	Rated	Rated	Rated
8	LINE8	Closed	Rated	Rated	Rated
9	LINE9	Closed	Rated	Rated	Rated

Table (9): Performance Summary of the IMDG unit for faulty operation.

The graphical representation of the breaker currents of the IMDGU breakers under faulty operational conditions are illustrated in figure (6).

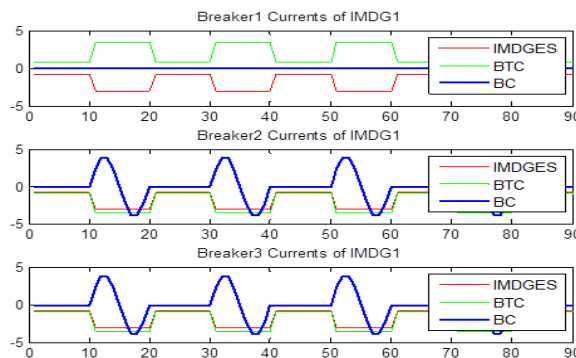


Fig (6): Breaker currents of the IMDG Unit breakers under faulty condition.

The power quality checking of the OG-HPS is done as follows.

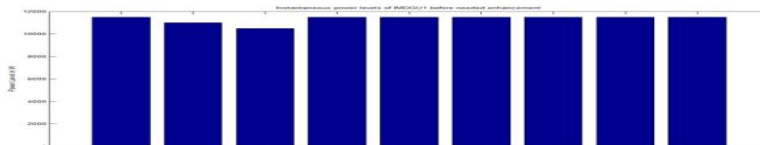


Fig (7): Instantaneous power levels of the OG-HPS bus lines before the needed enhancement.

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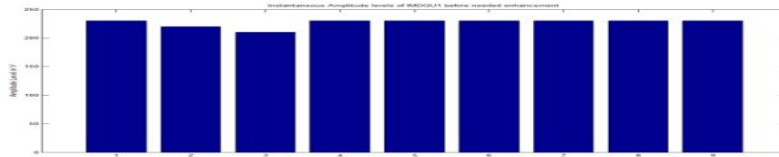


Fig (8): Instantaneous amplitude levels of the OG-HPS bus lines before the needed enhancement.

The power quality regulation and enhancement of the OG-HPS is done as follows.

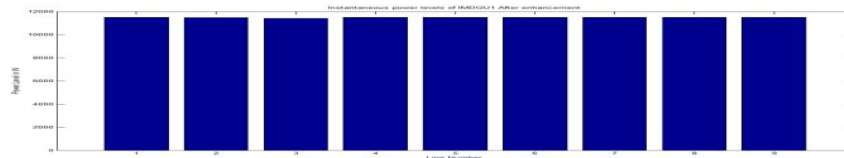


Fig (9): Instantaneous power levels of the OG-HPS bus lines after the needed enhancement.

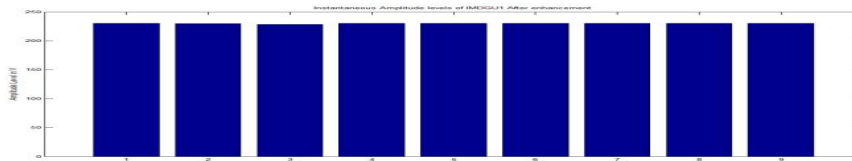


Fig (10): Instantaneous amplitude levels of OG-HPS bus lines after the needed enhancement.

IV.CONCLUSION

The Robust and fault free operation of an OG-HPS can profit the power distribution company, network and also the consumers. Spurious disturbances in the quality of the power supplied by the OG-HPS not threaten the operational effectiveness of electrical utilities, but also destroy their internal circuitry leading to a huge production loss to the consumer industries. The power deviations due to line faults cannot be tolerated easily, until or unless the fault is detected and isolated. Some years of research was devoted to find an optimal mean for an efficient power quality correction and improvement. And as a result of which many algorithms were proposed in the literature which could not meet the present application demands. In this scenario in order to provide an eternal solution to the aforementioned problems we developed this algorithm. The concept of IMDGU is completely new and practically very efficient. Each IMDG unit encapsulates two major processing units which are PMU and PQRU. These two units will work in coordination with each other to maintain the regulated power quality of supply. The proposed approach is practically coded and simulated in MATLAB software. Simulation results adjudge that the proposed algorithm is best in all aspects and outperforms all the existing methods.

V.FUTURE WORK

For simplicity and to reduce the complexity, the proposed approach is practically realized with 9-line ring bus architecture. But there is no limit on the size of the network and hence it can be extended to any large size OG-HPS and any higher order bus. Increase in the physical size of the OG-HPS network doesn't cause any performance deviations. As a consequence the physical size and processing capability of the internal components has to justify with the proper selection of internal components of matched capacity and efficiency.

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